Space Technology Research Grants

Modeling, Testing, and Simulation of Heavy-Ion Basic Mechanisms in Silicon Carbide Power Devices

Completed Technology Project (2017 - 2020)

Project Introduction

Power management and distribution systems in future NASA flights would benefit greatly from high-voltage DC power, both to reduce power losses and to facilitate solar electric propulsion, the use of ion drives powered by photovoltaic arrays. Silicon Carbide (SiC) power transistors are ideal electrical candidates for these applications, but heavy-ion radiation tests (in particle accelerators simulating the radiation environment experienced by space-borne electronics) of Silicon Carbide power diodes and SiC power MOSFETs reveal two unexpected phenomena: 1) discrete, permanent increases in off-state current with each ion strike; and 2) a single-event-burnout (SEB) type of hard failure where off-state current increases suddenly to destructive levels after an ion strike at bias levels only a fraction of the device maximum voltage rating. Experimentally observed heavy-ion behavior in SiC power devices is not currently captured in Poisson-solver Technology Computer-Aided Design (TCAD) finite-element simulation programs. It is unclear why the heavy-ion response of SiC devices differs so much from that of silicon power diodes and MOSFETs. Possible explanations include the wide band-gap and complex band structure of SiC, the anisotropic structure of the SiC crystal, lattice defects, and local disruption of the crystal structure by the energy deposition of the heavy ion. This work will seek to identify the physical mechanisms in the heavy ion response of SiC power devices through physical analysis, electrical and radiation testing, and device simulation, and to develop new and appropriate physics models for TCAD device simulation software that facilitate describing these physical mechanisms and their effect on device behavior. Once these mechanisms are well-understood, mitigation measures can be undertaken by device manufacturers to make the next generation of SiC devices less vulnerable to radiation effects, enabling NASA to use these power transistors to achieve their goals of high voltage, highly efficient, lightweight and compact space power systems.

Anticipated Benefits

Reduction in size, weight, power for power management and distribution (PMAD) of future space missions. Road map to radiation qualification of SiC power devices for space missions. Radiation-robust SiC power diodes and transistors available from major device manufacturers.

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Table of Contents

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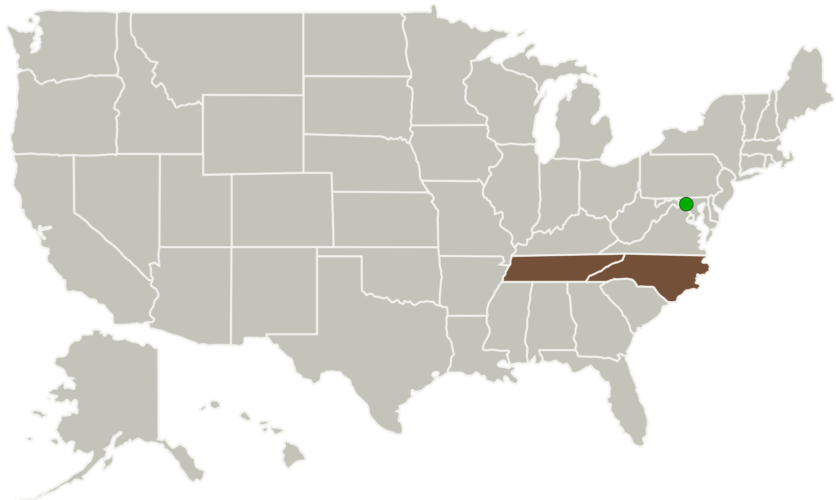
Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Vanderbilt University	Lead Organization	Academia	Nashville, Tennessee
CREE Inc.	Supporting Organization	Industry	
Goddard Space Flight Center(GSFC)	Supporting Organization	NASA Center	Greenbelt, Maryland
University of Jyvaskyla	Supporting Organization	Academia	Jyväskylä, Outside the United States, Finland

Primary U.S. Work Locations	
North Carolina	Tennessee

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

Vanderbilt University

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

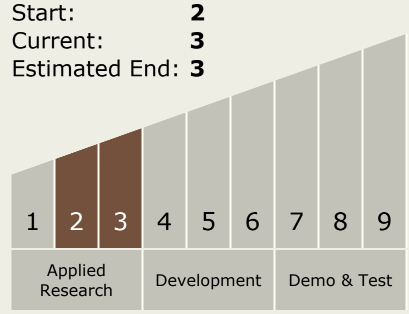
Hung D Nguyen

Principal Investigator:

Kenneth F Galloway

Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **3**



Project Website:

https://www.nasa.gov/strg#.VQb6T0jJzyE

Technology Areas

Primary:

- TX11 Software, Modeling, Simulation, and Information Processing
  - └ TX11.1 Software Development, Engineering, and Integrity
    - └ TX11.1.6 Real-time Software

Target Destination

Outside the Solar System